SUMMARY OF SESSION ON JETS AND INCLUSIVE HADRON PRODUCTION

M. WING
University of Bristol, DESY, Notkestrasse 85, 22607 Hamburg, Germany
E-mail: wing@mail.desy.de

Some highlights of the session on jets and hadron production are summarised. Results between different experiments and measurements are compared and, in particular, how LEP and HERA complement each other discussed. Improvements in both theory and experiment for jet and hadron production and how the measurements can be used to extract fundamental parameters are addressed.

1 Introduction

Measurements of jets and hadron production at both LEP and HERA provide detailed investigations of many facets of Quantum Chromodynamics (QCD). They provide constraints on the parton densities in both the photon (LEP and HERA) and proton (HERA) in a complementary way to the inclusive measurements of the structure functions, F_2^γ and $F_2^{\rm p}$. The cross sections are also sensitive to the dynamics of the hard sub-processes and perturbative QCD (pQCD) calculations. The transition of partons into hadrons can also be measured, thereby bridging the gap between pQCD calculations in terms of partons and the hadrons seen in detectors.

A lot of precise data exist in jet and hadron production from LEP and HERA, some of which are here discussed. For some results all of the available data from LEP has been analysed and at HERA the interpretation of many measurements is becoming limited by large theoretical uncertainties. To ensure that the data has a legacy, global fits to parton densities and Monte Carlo (MC) tuning need to be done incorporating much of this data. This will improve future measurements at both HERA and other colliders, in particular the LHC where very precise knowledge of the proton is needed.

2 Summary of results

2.1 Hadron production

Measurements of hadron production testing both the fragmentation [1] and production mechanism [2,3] were presented. At LEP, the L3 collaboration have measured π^0 and K_s^0 production and compared them with predictions from NLO calculations, MC models and an exponential fall-off as shown in Fig. 1.

The cross sections as a function of the transverse momentum of the hadron, p_t, are described by an exponential at low p_t and by a power law function, Ap_t^{-B}, at values larger than 1.5 GeV. The value of the power B is compatible with 4 for both π^0 and K_s^0 mesons as expected in $2 \rightarrow 2$ hard parton scattering [4]. Both the MC and NLO predictions give qualitatively similar results. At low p_t they describe the data well, but fail at high p_t in the cross section for π^0 production. It would be of interest to see the distribution to higher values for the K_s^0 cross section, but this will be unattainable at LEP.

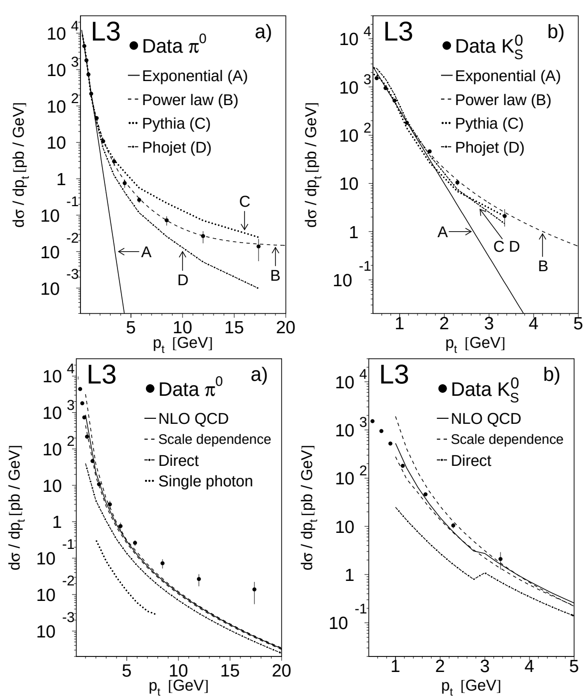

Figure 1. Inclusive differential cross section, $d\sigma/dp_t$, compared to MC and NLO predictions and exponential and power law behaviour for π^0 and K_s^0 production.

At HERA large samples of K_s^0 mesons exist, extending up to transverse momenta of ~ 8 GeV, which could verify the preference of the power law also for this meson. The production of K_s^0 and Λ hadrons has been considered at HERA and their relative rates compared to MC predictions. When the MC predictions are normalised to the measured K_s^0 production cross section,

predictions from HERWIG overestimate and from PYTHIA underestimate, the Λ productions cross section.

2.2 Prompt photon production

The description of prompt photon production by QCD at hadron colliders has long been an issue of interest. The current status of comparison between data and theory is shown in Fig. 2 in which clear discrepancies are seen over a large range in energy [5]. In particular, at the Tevatron, the data from both D0 and CDF is not well described, particularly at the lower transverse energies. Explanations for this discrepancy in prompt photon production vary,

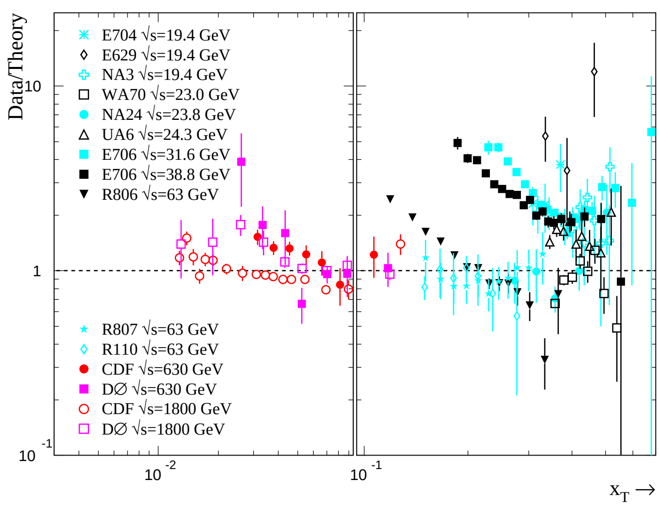

Figure 2. Comparison of data and QCD predictions for prompt photon production in hadron-hadron collisions

for example the need for resummed calculations or extra k_T in the colliding hadron being invoked. In this light, ZEUS have made an extraction of the k_T in the proton using a sample of events with a prompt photon and an approximately back-to-back jet. This was extracted by considering variables sensitive to k_T and fitting the PYTHIA MC predictions to these distributions. The value found was consistent with a trend of increasing k_T with increasing centre-of-mass energy. However, a recent NLO calculation [6] of prompt photon and jet production can describe the k_T-sensitive variables, with no extra k_T required. In fact, calculations from the same group [7] can describe most of

the hadron-hadron measurements shown in Fig. 2. Those data not described have found to be inconsistent with other measurements [7].

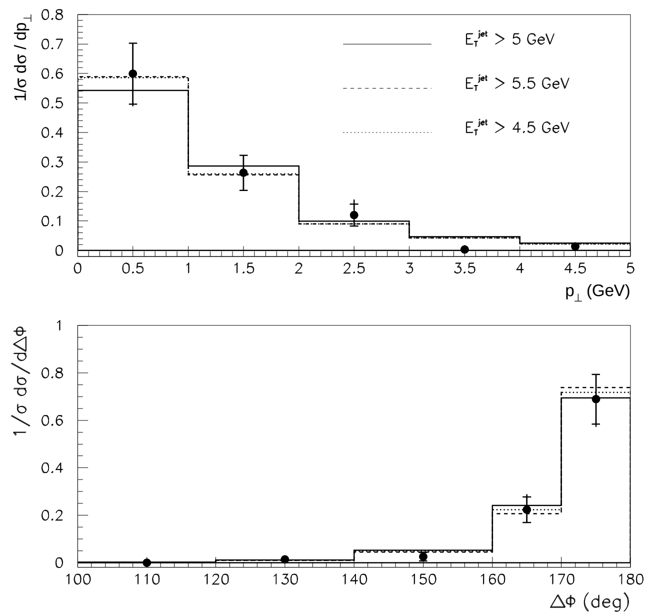

Figure 3. Measured normalised cross sections for transverse momenta, $p_\perp$ and angle, $\Delta\phi$, of the photon relative to the jet compared to NLO.

2.3 Jet production

Jet production is being extensively studied in $\gamma\gamma$ collisions at LEP [8] and *ep* collisions at HERA [9]. The measurements investigate the detailed dynamics of QCD, the parton densities in the photon and proton and allow measurements of the strong coupling constant, α_s.

The dijet production cross section in $\gamma\gamma$ collisions is sensitive to the gluon content of the photon at LO. To try and constrain this, the cross section has been measured by both the DELPHI and OPAL collaborations [8]; the measurements are consistent with each other. Using a luminosity of ~ 600 pb^{-1}, some results from OPAL are shown in Fig. 4 compared to prediction from NLO and the PYTHIA MC. In the region of high-$x_\gamma^\pm$, the NLO and PYTHIA MC prediction describe the data well. For the case of single resolved

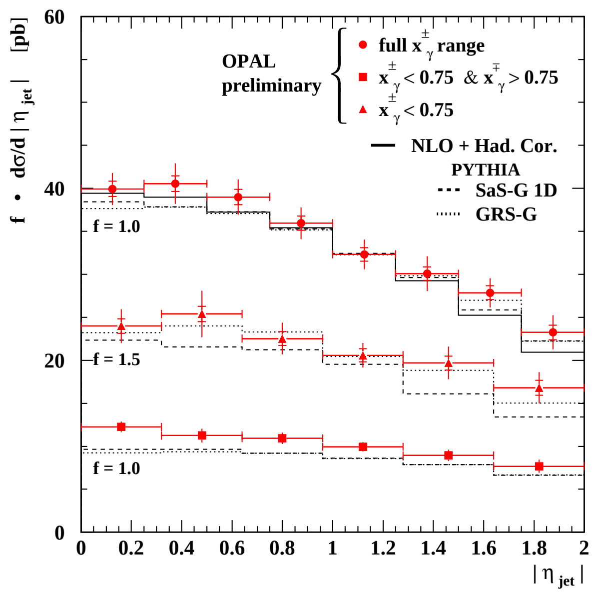

Figure 4. Measured cross sections as a function of pseudorapidity, compared to predictions from NLO and PYTHIA MC. The measurements are shown in different regions of $x_\gamma^\pm$.

events at low-$x_\gamma^\pm$, the PYTHIA prediction underestimates the data by about 20%. The cross section in x_γ is very sensitive to hadronisation effects and needs to be studied further. The accurate data can be used in future fits to constrain the parton and in particular the gluon density in the photon.

To make dijet measurements, the cuts on the jets have to be chosen carefully so as not to be infra-red sensitive. This has been extensively studied at HERA. The cuts on the two jets have to be sufficiently different to allow for soft-gluon emission. This region can be seen in Fig. 5 at high values of $E_{T,2}^{\rm jet,cut}$, where the NLO prediction has very small uncertainties and overshoots the measured cross section. At low values of $E_{T,2}^{\rm jet,cut}$, the data and NLO have similar shapes for high-$x_\gamma^{\rm obs}$ and very different shapes for low-$x_\gamma^{\rm obs}$. Although the NLO and data agree within the uncertainties, the inclusion of higher orders would require a significant change in shape. This could also indicate problems with the photon parton densities, and higher order calculations would help further constrain them. It should be noted that the predictions

from the HERWIG MC describe the shape of the data well. It is normalised to the total cross section for the full $x_\gamma^{\rm obs}$ region and $E_{T,2}^{\rm jet,cut}$ =11 GeV.

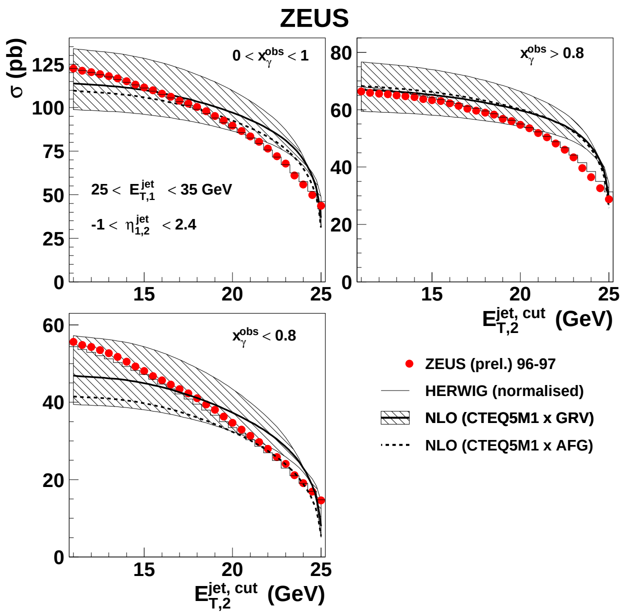

Figure 5. Measured cross sections as a function of the cut on the second highest transverse energy jet, $E_{T,2}^{\rm jet,cut}$ compared to prediction from NLO and HERWIG MC.

3 Discussion

Some measurements of jet and hadron production have been discussed. Calculations to NLO QCD do not give a complete description of all the measurements. With the large data samples now collected at LEP and HERA, these precise measurements could be used to constrain parton density functions and tune MC's. Important theoretical work is needed in producing higher order calculations and/or NLO calculations with parton showers [10] and hadronisation. Both of these projects have started and are essential if theory is to keep up with the increasing precision of the data.

References

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